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CONTRIBUTIONS TO THE ESTABLISHMENT OF TMDL VALUES FOR THE UMATILLA RIVER WATERSHED

R.W. Rickman, J. Williams, C. Clifton, and M. Purser.

INTRODUCTION

The water quality of many streams in Oregon do not meet current Oregon state standards. The Umatilla River is among those water quality impaired streams. To address this problem the Oregon Department of Environmental Quality is working with the Umatilla Basin Watershed Council and the Confederated Tribes of the Umatilla Indian Reservation to establish values for the Total Maximum Daily Load (TMDL) of pollutants that can enter the river, yet allow the water quality to meet existing standards. Pollutants include nutrients such as fertilizer nitrogen and phosphorus, coliform bacteria, heat, soluble organic materials, and suspended solids. Biological growth of algae, bacteria, various aquatic insects, aquatic animals, and fish depend on water temperature for the balance of oxygen and nutrients to sustain their life cycles. To understand the growth and interactions of the various organisms living in the river, one must first understand the temperature fluctuations and cycles of the river. Water temperature in the river is dependent upon a very complex combination of water volume, stream channel characteristics, riparian vegetation, and weather.

To help describe and understand complex systems, models are often used. The water quality model named QUAL2E is available from the Environmental Protection Agency and has been used for assessing stream water quality problems at several locations throughout the United States. QUAL2E was created during the 70s and 80s in the southwestern United States. One of the objectives of this report is to examine the sensitivity of temperature predictions by QUAL2E to input weather and other model parameters. Another is to report on the collection of weather and water temperature data in the Umatilla Basin for the purpose of local calibration of the model. Objectives are not to match Umatilla River temperature patterns at this time, but to obtain sufficient experience and data to calibrate QUAL2E so that its computed responses are suitable for application to the Umatilla River.

Each time that QUAL2E is run it computes a steady state picture of temperature in a river system. This means that for each tributary and point source that supply water to the river, a constant flow rate and water temperature must be provided as input for the model. Output from the model is a pattern of temperature with distance along the length of the river. If a projection of river temperature is wanted for different flow volumes or inflow temperature conditions, a separate run of QUAL2E must be made using the specific flow volume and temperature conditions of interest.

For internal computations QUAL2E represents the river as a series of adjacent sections, called reaches. A reach may be as short as 1 mile or as long as several miles. Each reach represents a section of the river that has, at a scale of 1 mile increments, the same hydraulic or environmental characteristics such as river width, channel slope, channel roughness, or shading. Weather conditions such as air temperature, solar radiation, wind, and dew point temperature can be treated as identical for the full length of the river or they can be specified separately for each reach. River water temperature computations within QUAL2E are based on a conservation-of-energy budgeting procedure. Water temperature is modified by radiation energy from sunlight, heat conduction and radiation from air and the river bed, and evaporative cooling in addition to the mixing of waters of different temperature from tributaries or other sources.

PROCEDURE

The effects of changes in four environmental parameters (volume of water flow, solar radiation, air temperature, and wind speed) that are required inputs to QUAL2E were examined. Radiation, temperature and wind were treated as if they were constant for the full length of the river in order to examine the performance of QUAL2E in the simplest possible situation. The test values used for each parameter, listed in Table 1, provided sets of initial conditions for multiple runs of QUAL2E.

Table 1. Extreme values of environmental input variable used to examine calculations from QUAL2E. Values are representative of the Umatilla River between May and August.

Input Variable	High	Low	Units
Solar Radiation	786	395	Langleys/Day
Water Flow	700	100	cfs at Nolan
Air Temperature	90	70	F
Wind	10	0	mph

Several reaches were created to approximate the various hydraulic changes along the Umatilla River from the South Fork above Shimmiehorn Creek to Nolan below Pendleton (Figure 1 and Table 2). All water entering the river from head waters and tributaries was given a 50° F initial temperature so that only the test parameters, not input temperature, would modify the model outputs. The model outputs for water temperature of a river in one mile increments were compared for various combinations of the four test parameters.

Several recording thermometers were placed in selected locations in the Umatilla River and its tributaries in May of 1996 as part of the monitoring program of the TMDL committee of the Umatilla Basin Watershed Council. They were retrieved in September. Some of these temperature records will be used to calibrate QUAL2E.

Table 2. Reach segments, illustrated in Figure 1, for the Umatilla River from South Fork to Nolan.

Reach Name (Abbreviation)	Beginning River Mile	Beginning Elevation	Slope ft/ft	Man N
UMATILLA				
South Fork (SF)	97	2870	0.025	0.04
Corporation (CP)	91	2320	0.02	0.035
Reservation Tributaries (RT)	80	1750	0.005	0.025
Residential (RL)	61	1300	0.005	0.02
Canyons (CN)	50	950	0.003	0.02
TRIBUTARIES				
Meacham(MM)	19	2750	0.02	0.035
McKay (MK)	7	1350	0.01	0.02

RESULTS AND DISCUSSION

Figures 2 and 3 illustrate the water flow and in stream temperature patterns from QUAL2E for low and high flow of water in a river for unshaded - no wind, shaded - no wind, unshaded - 10 mph wind, and shaded - 10 mph wind input on a hot (90° F) August day. The projected temperatures in Figure 2 are, as should be expected

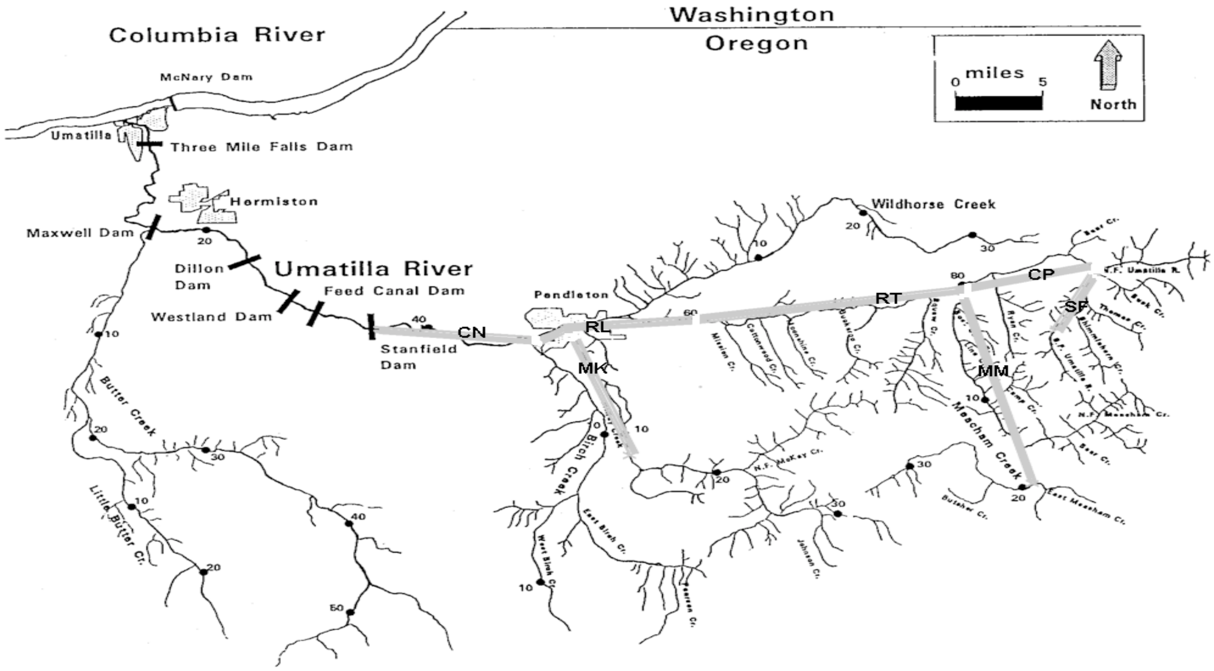

Figure 1. Location of reach segments, described in Table 1, representing water flow in the Umatilla River

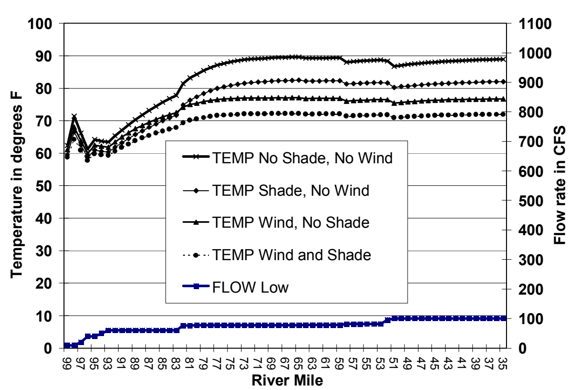

Figure 2. Temperature patterns predicted by QUAL2E in a river with low flow, high air temperature.

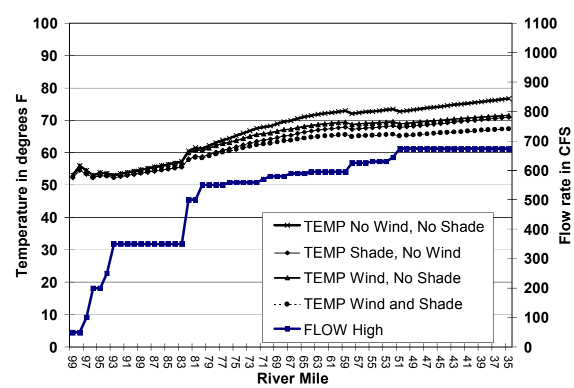

Figure 3. Temperature patterns predicted by QUAL2E in a river with high flow, high air temperature.

with the low water flow, warmer in all reaches than with the high water flow represented in Figure 3. The temperature patterns in Figure 2 indicate that for the low flow condition, water temperature had increased to near a maximum value by approximately river mile 75 for all 4 combinations of wind and shade input conditions.

With the high flow of Figure 3, river temperature was projected to remain cooler and not reach a maximum temperature condition within the length of river that was analyzed.

In Figures 4 and 5 input air temperature of 70° F vs. 90° F provided patterns of river temperature comparable to those predicted for a shaded vs unshaded river at 90° F air temperature in Figures 2 and 3. Wind of 10 mph in both cases was predicted to reduce river temperature by a surprisingly large amount. If the effect of wind is truly that large, it will be important to measure wind at several sites along the river to interpret observed water temperatures. If

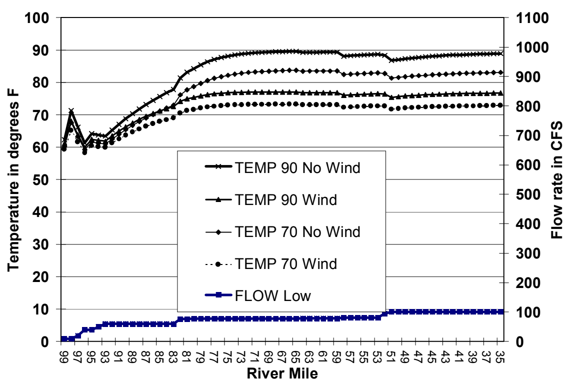

Figure 4. Temperature patterns predicted by QUAL2E in a river with low flow, high radiation, high and low air temperature.

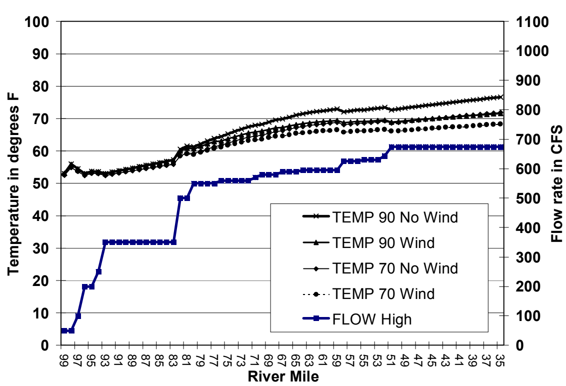

Figure 5. Temperature patterns predicted by QUAL2E in a river with high flow, high radiation, high and low air temperature.

the large effect of wind is not found in observed river temperature data, input wind values must be held constant when other parameters are investigated with QUAL2E.

Observed daily solar radiation, average air temperature, and total daily wind records for 1996 from the Columbia Plateau Conservation Research Center near Pendleton and IZR Consulting near Hermiston were compared to characterize the range of environmental conditions from the mouth to approximately river mile 65 in the Umatilla Basin. Figures 6,7, and 8 illustrate a consistent high correlation between locations for all three parameters. For the Umatilla Basin

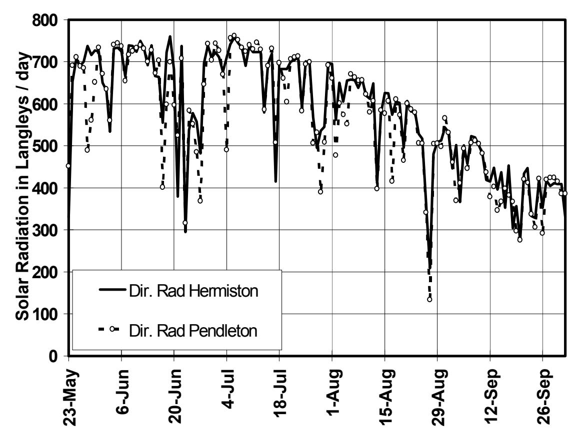

Figure 6. Solar radiation at Pendleton and Hermiston for 1996.

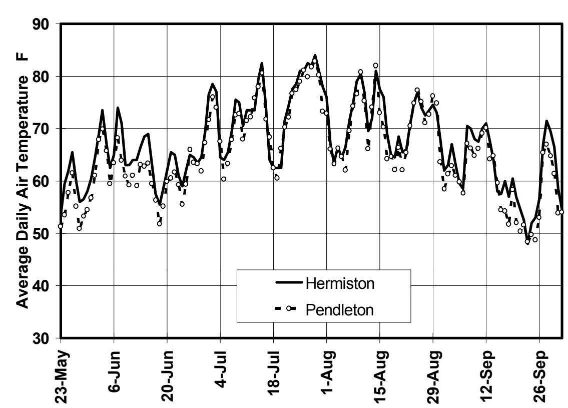

Figure 7. Average daily air temperature at Pendleton and Hermiston for 1996.

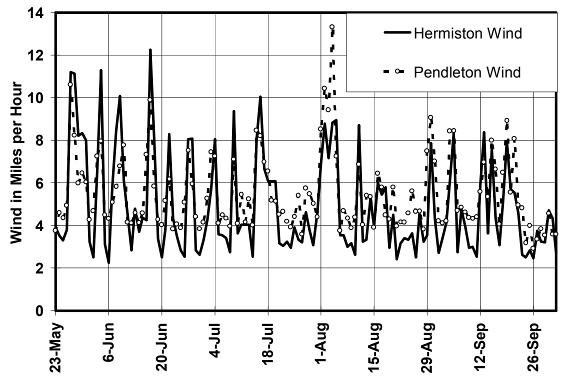

Figure 8. Daily wind at Pendleton and Hermiston for 1996.

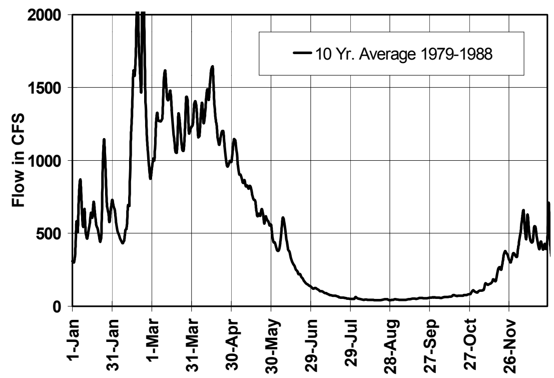

Figure 9. Ten year average of water flow in the Umatilla River at Pendleton Oregon

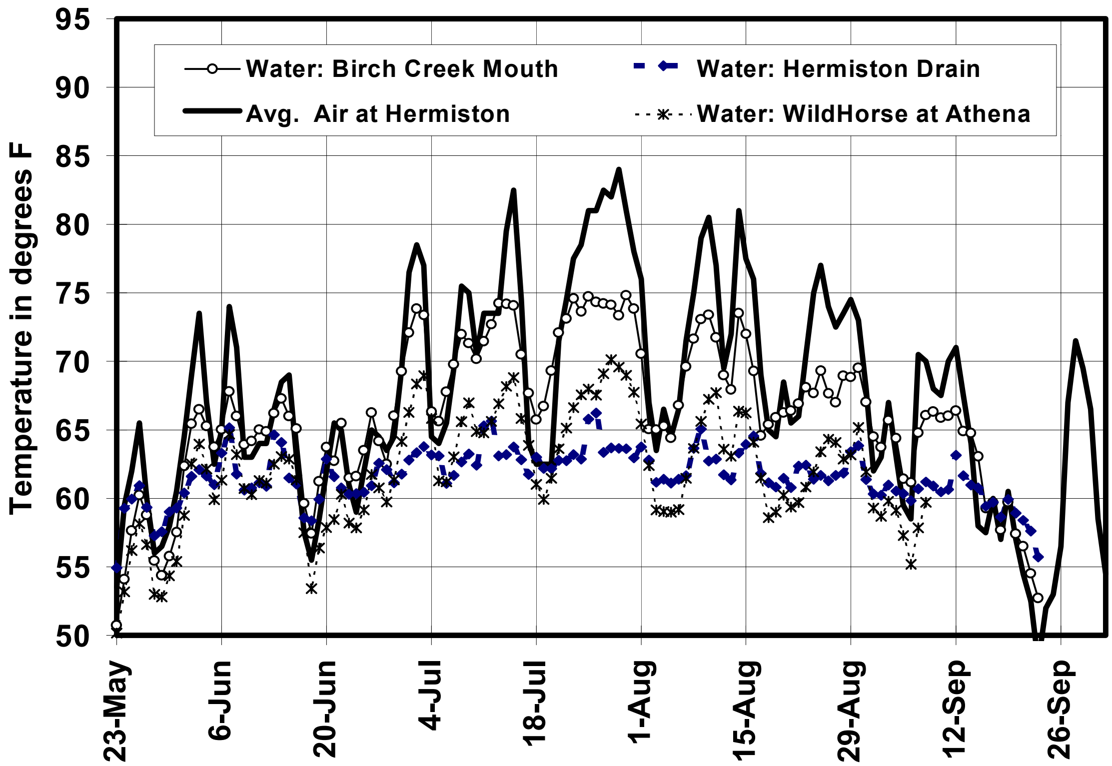

Figure 10. Water temperature at three locations in the Umatilla Basin in 1996.

from Pendleton to the mouth of the river at Umatilla OR., one set of environmental parameters (radiation, air temperature, and wind) could be used as a good first approximation of daily weather for all of the reaches.

Water flow and daily weather interact to control river temperature. Flow varies from year to year but does have a seasonal pattern. The 10-year average flow of the Umatilla River at the city of Pendleton is shown in figure 9. Water quality problems of the river are most evident during the low flow of the summer months.

Measured water temperature at three locations in the Umatilla Basin (Hermiston Drain, Birch Creek mouth, and Wildhorse Creek at Athena) are reported here for discussion and preliminary analysis. The water temperatures at all three locations are plotted with the Hermiston air temperature in Figure 10. The correlation of correlation (r^2) for water temperature and air temperature at each location are 0.66, 0.84, and 0.83 respectively. An r^2 value of 1.0 indicates perfect correlation and 0.0 is no correlation. Two thirds of the variation in water temperature at the Hermiston drain is related to air temperature, while over 80% of the water temperature variation at Birch creek and Athena is related to air temperature. Even though water and air temperature are closely correlated, each location has a different relationship between air and water temperature. At Birch creek water temperature changed about 0.6 degrees for each 1 degree change in air temperature. In Athena the water temperature change was 0.5 degrees for each 1.0 of air temperature, while at the Hermiston drain water temperature changed only 0.2 degrees for each 1.0 degree of air temperature.

The uniform and relatively low temperatures at the Hermiston Drain were a bit surprising. The thermometer was actually in the South Drain, not in the river. One of the major differences between the Hermiston drain and Birch Creek, for example is shading. The Hermiston Drain measurement site was totally shaded by Russian Olive trees while there was no shade from any source at the mouth of Birch Creek. Extreme fluctuations in temperature that are present in the water at the mouth of Birch Creek are not present at the Hermiston Drain site. Shading at Athena is intermediate to the Birch Creek and Hermiston Drain sites. When water temperature at any of three sites is regressed with air temperature, from either Pendleton or Hermiston, the difference between observed water temperature and that computed from air temperature is not related to wind. This is a good example of why models must be calibrated to local conditions. The calculated difference between water temperature with and without wind blowing by the default parameters in QUAL2E seems to be much greater than would be expected from the water temperature, air temperature, and wind observations recorded during the summer of 1996.

The water flow data for 1996 from the various tribuaries are not yet summarized. When those data are available they will be combined with the temperature data from the tributaries and other sites along the Umatilla river to calibrate QUAL2E to the Umatilla River. QUAL2E will then be used to examine the nutrient budgets of the river and help to display patterns of water quality along the length of the river. Once these computed patterns are suitably matched with water quality measurements taken from the river, QUAL2E will be used as one of several tools for guiding the selection of appropriate TMDL values to bring the water of the Umatilla River into compliance with Oregon State water quality standards.